TECHNICAL REPORT 1792
March 1999

Cognitive and Behavioral Task Implications for Three-Dimensional Displays Used in Combat Information/ Direction Centers

M. F. Eddy
H. D. Kribs
Instructional Science
and Development, Inc.

M. B. Cowen
SSC San Diego

Approved for public release;
distribution is unlimited.

SPAWAR
Systems Center
San Diego

SSC San Diego
San Diego, CA 92152–5001

SSC SAN DIEGO
San Diego, California 92152–5001

H. A. Williams, CAPT, USN
Commanding Officer

R. C. Kolb
Executive Director

ACKNOWLEDGMENTS

This study was conducted with the assistance and cooperation of the Surface Warfare Officer's School, Newport, RI, and the Navy Technical Training Center, Corry Station, Pensacola, FL. We would like to thank Captain Bill Marks (USN, RET), Lieutenant Commander Robert Foor (USN), and the instructors and students at both schools who participated as subject matter experts and contributed their time and skill in performing this analysis.

The authors would like to thank and acknowledge the following individuals who reviewed this report for technical accuracy: Dr. Robert Smillie, Mr. Orv Larson, and Mr. Rey F. Yturralde from SSC San Diego; Lieutenant Commander Karl Van Orden from the Naval Health Research Center, and Commander Jeff Bacon from the Space and Naval Warfare Systems Command.

EXECUTIVE SUMMARY

This report discusses an investigation to determine which tactical information should be displayed in three dimensions (3-D), as visualized data that would be beneficial to the warfighter's understanding of the battlespace. A cognitive task analysis was conducted using warfighting personnel from Surface Warfare Officer's School (SWOS), Joint Maritime Command Information System (JMCIS) instructors at Navy Technical Training Center, Corry Station, and participants at the "All Service Combat Identification and Evaluation Team, 1997" combat training exercise. Our task analysis found that a 3-D display could enhance situation awareness by providing a succinct, comprehensive, and readily discernable presentation of the common tactical picture. 3-D displays could aid tactical decisionmakers in three general cognitive/perceptual areas: (1) assessing the force structure of friends, neutrals, possible adversaries, and noncombatants, (2) anticipating possible future actions based upon capabilities, historical precedent, and current political climate, and (3) refining and rehearsing contingency plans based on an assessment of the possible threat. Our analysis examined these processes and determined that a 3-D display could provide enhancement in submarine and mine location/interdiction, amphibious assault/land support, and air warfare planning and execution.

CONTENTS

Figures

Tables

INTRODUCTION

PROBLEM

Little data has been collected to support effective implementation of three-dimensional (3-D) technologies so users can better understand and manipulate specific tactical displays to achieve the common tactical picture (CTP). Designers of future Command, Control, Communications, Computers, and Intelligence (C4I) systems are now considering using advanced graphical methods to assist the user in acquiring and maintaining the CTP, including the use of perspective 3-D displays. Commercial development of these methods is maturing, and commercial display vendors are forecasting that the window of opportunity to provide human performance guidance to C4I acquisition managers is closing quickly. Already, several industry- and government-funded university laboratories have created and fielded test prototypes featuring 3-D rendering of tactical information.

The Department of Defense and other federal government agencies are seeking to leverage advanced information technologies to improve training and job performance of personnel performing in increasingly complex working environments. The opportunity exists to use new enabling technologies to develop, produce, and apply advanced human–machine interface designs in performing complex command and control tasks. It is anticipated that these technologies can enhance situation awareness and assist task performance more effectively than current designs.

C4I systems should help the user understand the CTP in a battlespace environment that is constantly changing and that fluctuates in size. The CTP is all information spanning the spectrum from the sensor to the shooter that allows tactical commanders to understand the battlespace. Knowing the CTP represents a great cognitive challenge because the system operator must be able to remember and interpret complex data sets while maintaining battlespace situation awareness.

OBJECTIVE

The objective of the study was to perform a task analysis, including both behavioral and cognitive elements, for using a specific C4I system, the Joint Maritime Command Information System[1] (JMCIS). The task analysis for JMCIS was designed to identify those behavioral and cognitive elements of the CTP that can benefit from the display of 3-D images on flat screens. This study was performed in support of the SSC San Diego program called "Display and User Enhancement Technology for Systems (DUETS)."

---

[1] As of the last quarter, FY 1998, JMCIS is referred to as Global Command and Control System–Maritime (GCCS-M).

BACKGROUND

Experienced decisionmakers are not necessarily well-served by current display systems when performing demanding missions (Morrison, Kelly, and Hutchins, 1996). Decisionmakers suffered periodic losses of situation awareness, which were often associated with limitations in human memory and attention capacity. Difficulties linked with short-term memory limitations include: (1) confusing and forgetting track numbers, (2) confusing track kinematic data (track understood to be approaching vice departing or climbing vice descending) and forgetting track kinematic data, and (3) combining past track-related events/actions with incorrect tracks and associating completed ownship actions with incorrect tracks. Information ambiguity and time constraints also combined to increase decision biases, causing other difficulties including: (1) using initial threat assessment throughout the scenario regardless of new information, and (2) judging a track with information other than that associated with the track.

JMCIS is a command and control tool that integrates a variety of independent radar and communication systems and provides a complete tactical representation about an area of interest. The function of JMCIS is to provide ready access to unambiguous, timely, tactical information on which the commander can build a comprehensive view of the tactical situation (Surface Warfare Officers School Command, 1996). Appendix A summarizes JMCIS capabilities. JMCIS systems are used on ships to a greater or lesser extent depending upon the platform's configuration and capabilities. Shipboard command and control functions are currently accomplished through various display and coordination systems. Figure 1 shows a current hierarchy of shipboard information systems.

JMCIS/GCCS-M

CTP/Planning and Situational Assessment/Common Operational Picture (COP)

JTIDS (Joint Tactical Information Display System, incorporating Link information)

Tactical Decisionmaking

CEC (Cooperative Engagement Capability)

Sensor-Level Data Analysis

Figure 1. Shipboard information systems.

Depending upon the ship type and size, there will be one or more JMCIS terminals in the Combat Information/Direction Center (CIC). A frigate may only have one JMCIS display at the Tactical Action Officer (TAO) console, while an aircraft carrier will typically have four or more JMCIS displays at various watchstations and a large-screen JMCIS display at the TAO console. Appendix B describes functions of this equipment.

The communication and information assimilation process among various watchstations and the TAO is complex and fluid. About 20 percent of verbal communications clarify track location, kinematics (flight characteristics), identification, and priority (Morrison, Kelly, and Hutchins, 1996).

Figure 2 shows an organizational diagram for an aircraft carrier's CIC, which reflects many of the modules found on other surface combatants.

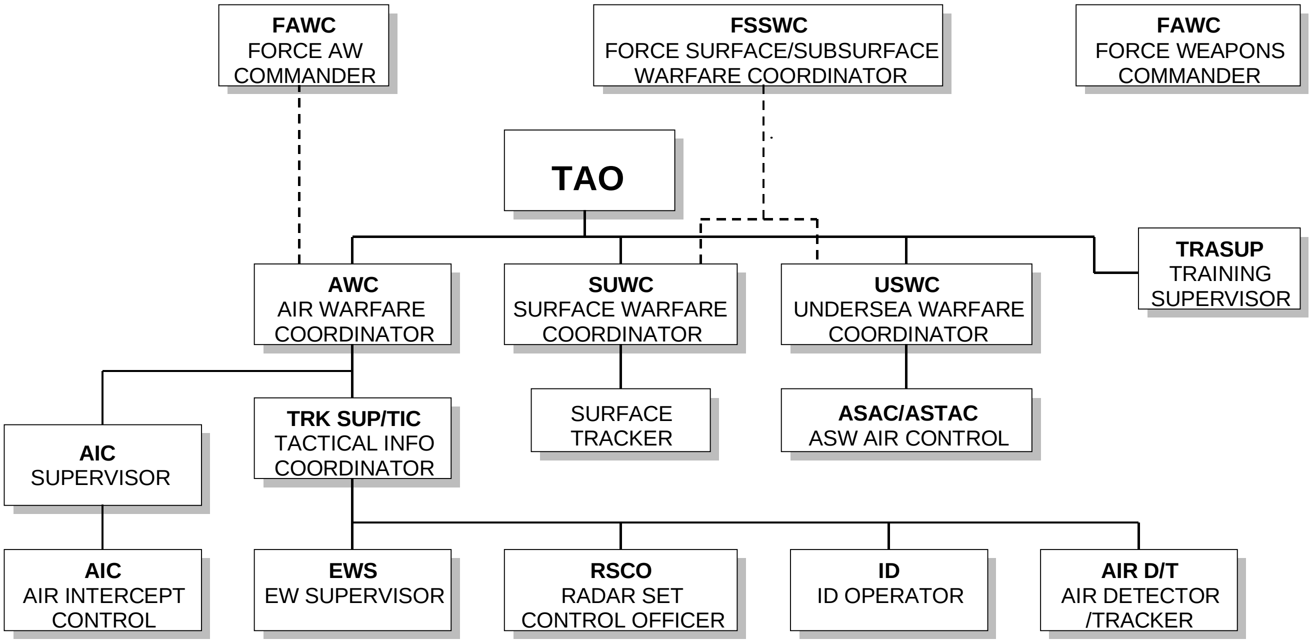


Figure 2. Aircraft carrier CIC organizational structure.

Information flow paths among the modules will vary depending upon ship type, watchstations, and support capabilities. For analysis of an area, users typically use two-dimensional (2-D) large-screen displays to develop strategies, predict future actions, and coordinate control of the battlespace. Three-dimensional (3-D) technology may be required to enhance this information flow/dissemination and to reduce the need for verbal clarification.

APPROACH

Data were collected using a behavioral task survey and a cognitive task analysis. Although the focus of this study was to identify the behavioral and cognitive elements of JMCIS, the scope was broadened to look at all displayed information used in tactical decisions because of the possibility that relevant data might be overlooked.

TASK SURVEY

The behavioral elements were identified using the Task Survey (Appendix C). The survey elicited responses on criticality, frequency, and difficulty regarding specific tactical procedures that involved displayed information. Survey questions were derived from a review of Surface Warfare Officers School's JMCIS Student Workbooks and other training materials from air and surface warfare courses (e.g., lesson plans and personnel performance profiles).

COGNITIVE TASK ANALYSIS

The Applied Cognitive Task Analysis (ACTA) methodology developed by Klein and Associates in 1997[2] was selected as the basis for the cognitive task analysis because it allows cues and sources of information to be derived within the context of situation awareness (SA). ACTA analyzes an individual's mental representation of SA and looks at the differences between novice and expert processes as well. We modified the ACTA methodology to specifically incorporate Endsley's (1987, 1988) SA framework.

Situation awareness, as defined by Endsley, is a threefold process including (1) perception of the elements in the environment within a volume of time and space, (2) comprehension of meaning, and (3) projection of status in the near future. The three parts of this definition provide a crucial understanding of the processes used to comprehend and make decisions based upon displayed information. At the first cognitive level, the user detects the target cues or objects in the environment. During the second cognitive level, the perceived information is processed and integrated into an assessment of the situation. At the third cognitive level, new projected outcomes are formulated for the situation. The element of time is essential in this definition, with the user's ability to understand the past facilitating an interpretation of present events (Harwood, Barnett, and Wickens, 1988). Past and present awareness then combine, allowing the user to predict future actions.

To be beneficial, in accordance with the Endsley structure, a command and control display must enhance SA in at least one of the following ways:

- Provide a greater perception of the relevant elements,
- Increase comprehension of the data provided,
- Reduce task loads.

Accomplishing any of these will enhance the user's ability to predict action, which is the desired result. The display must make the operator/evaluator's analytical decisions more informed and less

---

[2] L. Militello. 1997. "Applied Cognitive Task Analysis." Unpulished Technical Document. Klein Associates, Fairborn, OH.

difficult. A useful 3-D display must provide the user a complete picture of air, surface, and subsurface tracks to aid in timely and optimal decisionmaking.

The quality of SA is moderated by four factors: (1) capabilities, (2) training and experience, (3) preconceptions and objectives, and (4) ongoing task workload (see Endsley and Rodgers, 1994). Gerson (1997) contends that other influences to situation awareness include attitude and emotional state, and prior knowledge. Figure 3 shows all of these elements. The relative importance of these factors is situation-dependent. However, task workload and stress can be overriding components. Researchers have suggested that well-managed, short-term memory can alternate between about seven separate tasks during non-stressful scenarios with a reduction to two for stressful situations (Gerson, 1997). Choosing to concentrate attention on one set of events can only be achieved at the cost of diverting attention from all others (Adams, Tenney, & Pew, 1995). Therefore, as task workload and stress increase, decisionmakers will often lose "Big Picture" awareness and focus on smaller elements. Unfortunately, task workload often increases dramatically when key decisions are required, so an easily understandable presentation of relevant data is essential to the decisionmaker. Our cognitive task analysis was designed to identify those factors that may influence optimal operation of JMCIS.

ACTA uses three interview techniques (see Appendix D): (1) a Task Diagram, (2) a Knowledge Audit, and (3) a Simulation Interview to elicit information about specific tasks and determine the cognitive processes associated with those tasks. The tasks used to develop the Task Diagrams were selected through a review of background material and discussions with subject-matter experts. Interviewees were asked to think about a specific task, and then break down the process into three or more steps (but not greater than six). The Task Diagram for the "Evaluate an Area Picture to Predict Future Actions" task shown in Appendix D was found to consist of four steps: (1) understand history, (2) assess capabilities of possible adversaries, (3) evaluate intent of possible adversaries, and (4) predict actions.

A Knowledge Audit is then performed for each specific step in the Task Diagram. The goal of the Knowledge Audit is to elicit the expertise necessary to do each step. For example, for the specific step shown in Appendix D (assess capabilities of possible adversaries), interviewees were asked to provide different examples of this subtask with respect to past and future occurrences, the big picture, and their ability to notice meaningful patterns. For each example, the interviewees were asked to provide cues and strategies and asked why the example may be difficult to a less-experienced person.

The Simulation Interview is designed to discover any additional cognitive task elements that were not uncovered during the Task Diagram and Knowledge Audit. It accomplishes this by focusing on a specific scenario to provide a view of the task in context.

During the interviews, we deviated from ACTA to incorporate Endsley's situation awareness stages. We accomplished this by including probe questions in the Knowledge Audit and simulation interviews to ascertain what display features were currently missing or inadequately presented, especially those that could be included or enhanced with a 3-D display. These questions also solicited information regarding cognitive task loads in relation with displayed information, with an emphasis toward reducing cognitive loads through the use of 3-D technology. Appendix E lists the specific questions that were asked using the ACTA methods.

PROCEDURE

The Task Survey (Appendix C) was forwarded to the SWOS, Newport RI, where it was completed by six post department head/perspective executive officer instructors, and operational experts with command and control fleet experience. We conducted ACTA interviews at SWOS, the Naval Technical Training Center (NTTC), Corry Station, in Pensacola, FL; and the "All Service Combat Identification and Evaluation Team (ASCIET) 97" exercise held in Gulfport, Mississippi.

Individual interviews were conducted with eight Surface Warfare Officers (lieutenant commanders or commanders) at SWOS using the ACTA and situation awareness methods previously discussed, with the exception that no simulation interviews were conducted. Additionally, a roundtable discussion was held with four Surface Warfare Officers (commanders). All interviewed personnel had CIC work experience: TAOs, CIC Officers, Operations Officers, Executive Officers, or Commanding Officers.

Individual interviews were also conducted with six cryptographic technicians who had previously used JMCIS onboard ships and were currently serving as JMCIS instructors at NTTC, using the ACTA and situation awareness probe question framework.

Fifteen officer and enlisted operators and decisionmakers were interviewed at ASCIET. The objective of this joint 2-week exercise was to foster improved TTP (tactics, techniques, and procedures) across all combat ID (identification) mission areas. The field evaluation portion of ASCIET uses active, National Guard, and reserve personnel with current equipment. It involves military services, battle laboratories, doctrine commands, and tactics schools and offers a joint environment for emerging technology.

We conducted interviews based on live exercises that occurred each day. Representatives from the Marine Corps Tactical Air Operations Center and Air Force Command and Control personnel were individually interviewed at ASCIET using a combination of the ACTA simulation interview and situation awareness probing questions. They were also specifically questioned regarding physical display characteristics including size, layout, and format. Additionally, several command and control centers were observed during multiple scenarios to provide insight into processes, uses, and confusion/difficulties with regard to displayed information. The standard exercise scenario consisted of two attacks during a 5-hour vulnerability window with the main emphasis on air defense and close air support. Participating units included:

- Army: Battalion strength infantry, Patriot, Hawk, Archer, and manpad air defense systems.
- Navy: USS *Cape St. George* (Aegis Cruiser), F-14/F-18/S-3/EA-6/E2/H-3 aircraft.
- Air Force: Command/Control systems, F-15/F-16/E3/E8/A-10/H-60 aircraft.
- Marine: Command/Control systems, AV-8B/H-60 aircraft.

RESULTS

TASK SURVEY

Based on an analysis of the Task Survey data received from six SWOS respondents, several tasks were rated difficult to perform, performed frequently, and important to tactical decisionmakers. For each of the tasks in table 1, respondents provided a rating of one through five in the areas of criticality, frequency, and difficulty, with one being low and five being high. The results are listed to the right of each question.

The mean response ratings were grouped into three categories: (1) low (less than or equal to 2.5), (2) medium (between 2.5 and 3.5), and (3) high (greater than or equal to 3.5). Viewing the data using these categories, all tasks were rated as highly critical. However, only the following four tasks were found that were both highly difficult and of high frequency:

- Recognize and classify elements of air, surface, and subsurface threats.
- Determine threat capabilities.
- Predict future actions of threats.
- Adopt strategies and refine contingency plans based on predicted threat actions.

Note that some of the critical tasks that may not occur as frequently as the above may also be difficult to accomplish. If we look at medium frequency tasks, two other tasks were highly difficult:

- Develop a general battlespace overview.
- Resolve contact ambiguities.

The task survey also provided a section for respondents to comment on specific areas where they felt a 3-D display could aid in performance or any other comments (see Appendix F). Three respondents made comments, two of them indicating that a 3-D display would be particularly beneficial in a littoral environment, where land masses become an important consideration. The third respondent focused on a desire for a display that provided proximity ranges between objects of interest and visual cues to represent status changes. This person states that "we hate digital readouts because it takes longer to read and doesn't tell a story. Adding more info to a contact like its mode II, and track number and altitude and speed is not as good as representing these sorts of things in some other way that more intuitively paints a picture."

COGNITIVE TASK ANALYSIS

The following results were obtained from a combination of the three ACTA steps and situation awareness probe questions. Appendix G presents the ACTA task diagram results from individual respondents at SWOS, and identifies the complex cognitive processes required when evaluating an area picture to predict future actions. It is interesting to note the commonality of responses. Most interviewees described the same processes in slightly different ways. Evaluating intent of possible adversaries was sometimes mentioned before assessing capabilities. The Task Diagram in figure 3 summarizes these commonly identified processes.

Table 1. SWOS Task Survey data.

	CRITICALITY MEAN	FREQUENCY MEAN	DIFFICULTY MEAN
1. Locate significant topographical features on an operational area chart	3.7	2.3	1.8
2. Determine the effects of atmospheric conditions on platform capabilities	4.3	3.0	2.7
3. Employ environmental products to identify significant oceanographic features such as currents, ocean fronts and eddies, and upwelling	3.7	2.8	3.2
4. Recognize and classify elements of U. S. and allied forces	3.8	3.2	2.5
5. Determine overall capabilities of U. S. and allied forces	3.7	3.0	2.7
6. Recognize and classify elements of threats: air	4.7	4.3	3.8
surface	4.5	4.2	3.7
subsurface	4.5	3.8	3.8
7. Determine a contact's position (location, altitude/depth)	5.0	4.0	3.0
8. Assess a contact's position relative to other contacts	4.7	3.7	2.3
9. Evaluate a contact's motion (heading, velocity, ascent/descent)	5.0	3.7	2.7
10. Determine threat capabilities	4.7	3.7	3.7
11. Direct the control of aircraft in air intercepts/engagements (real/simulated)	4.3	3.0	2.8
12. Direct the control of aircraft in surface search/engagements (real/simulated)	4.0	2.8	2.7
13. Direct the control of aircraft in undersea search/engagements (real/simulated)	4.0	2.3	2.8
14. Direct the control of surface units in air defense (real/simulated)	4.3	3.0	3.2
15. Direct the control of surface units in surface actions (real/simulated)	4.0	2.5	2.7
16. Direct the control of surface units in undersea search/engagements (real/simulated)	4.0	2.2	3.2
17. Predict future actions of threats	4.7	3.5	4.2
18. Adopt strategies and refine contingency plans based on predicted threat actions	4.5	3.5	4.2
19. Develop a general battlespace overview	3.7	2.5	3.5
20. Maintain awareness of communications status	4.2	3.0	2.8
21. Resolve contact ambiguities	4.5	3.3	3.7

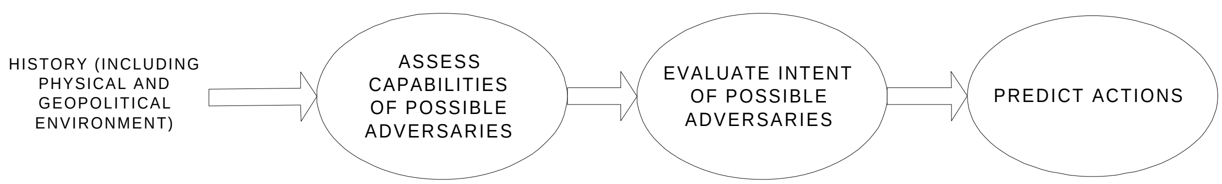


Figure 3. Task Diagram: Evaluate area picture to predict future actions.

Common Cognitive Task Elements. The Task Diagram data (Appendix G) reveal three general cognitive requirements to process displayed information. Of initial importance is assessing the force structure of friends, neutrals, possible adversaries, and noncombatants. This includes evaluating weapons and sensor systems (capabilities/ability to employ) and positioning constraints of these units. Since the U.S. Navy has shifted its concentration from "blue water" to littoral operations, this requirement may include an evaluation of land as well as sea assets. Second, the warfighter must anticipate possible future actions based upon capabilities, historical precedent, and current political climate. It is important to realize that in addition to anticipating what is likely to occur, the warfighter must anticipate and be prepared to react to “worst-case” possibilities. Third, the warfighter will refine and rehearse contingency plans based on an assessment of the possible threat. The actual courses of action will usually follow applicable tactics based on rules of engagement (Kaempf, Wolf, and Miller, 1993). It is interesting to note that these three cognitive requirements were also rated as high in criticality, frequency, and difficulty in our Task Survey.

Knowledge Requirements. All of the individuals surveyed stressed the importance of having background data regarding the area under observation. Adequate background data are needed to perform the cognitive task elements and should include as much detail as possible about potential military assets in the area (friend, neutral, and adversary), geographic constraints, observations of past occurrences, and the geopolitical climate. Several interviewees suggested the display of the battlespace in 3-D would lead to a more rapid understanding of the area under observation. Several of those surveyed also discussed the importance of ensuring dissemination of this information to all watch team personnel.

Novice and Expert Differences. Interviewees indicated that the perception of the battlespace of novice and expert watchstanders was different. Novice decisionmakers have more difficulty comprehending the third dimension (altitude) of battlespace. The interviewees also reported that novices had difficulties remembering weapon and sensor (both asset and threat) ranges and then projecting them into a tactical environment. Those interviewed also suggested that a 3-D graphic presentation would significantly heighten awareness of track location and ranges.

Task Overload and Stress. Interviewees reported that task overload occurs frequently and that a comprehensive graphical display of the arena in question would aid greatly for at-a-glance updates and general battlespace overview. Under conditions of task overload or high stress, tactical decisionmakers tend to mentally focus on specific tasks and lose “big picture” awareness. It was suggested that an alert feature to highlight new or changing tracks would reduce task overload.

3-D DISPLAY CONSIDERATIONS

One important consideration of any new display system is the window layout. There were differences among interviewees as to the placement of graphic and textual data. Some personnel expressed a desire for text windows that could be launched on top of the graphic display. Others preferred a dedicated section of the display for text and other information that would not hide the graphic presentation. Adding a second monitor for text information was also suggested. There was no consensus among those interviewed, but a greater number did prefer the version using adjustable text boxes that did not interfere with the graphic. Also, almost all persons interviewed stated that the display should have the capability to filter tracks to declutter the windows.

3-D Benefits for Inexperienced Decisionmakers. Inexperienced tacticians tend to think in 2-D. A 3-D perspective display would allow them to comprehend the vertical element of the area in question and use it in their decisionmaking processes. Also, the inclusion of selectable weapon and sensor envelopes would provide invaluable cues for planning actions. Our findings suggest that a 3-D display would immediately increase novice proficiency.

DISCUSSION

Our analysis of command and control tasks performed in the CIC found that the warfighter requires a succinct, comprehensive, and readily discernable presentation of the CTP. We found three general areas that require cognitive understanding of displayed information: (1) assessing the force structure of friends, neutrals, possible adversaries, and noncombatants, (2) anticipating possible future actions, and (3) refining and rehearsing contingency plans based on an assessment of a possible threat. We examined these processes and determined that a 3-D display[3] would benefit the warfighter in the following tactical arenas.

UNDERSEA WARFARE (USW)

The U.S. Navy is the best in the world at USW in blue water environments, but as operations move into the shallow littoral arena, their capabilities need enhancement. Systems are being upgraded to perform effectively against an enemy's quiet diesel-electric powered submarines. The USW combat system must be able to detect shallow water targets regardless of speed, aspect, or position. The detection problem is intensified in the littoral environment by factors including bottom contour and type, currents, and temperature gradients.

According to results compiled from expert operators and decisionmakers, a 3-D system could enhance detection abilities and reduce cognitive task loads by displaying underwater topography, currents, thermal layers, and sensor effectiveness. This would allow the operator/decisionmaker to more readily understand the battle problem, including sensor limitations, and conduct appropriate search operations facilitating a more optimal asset employment to discover and negate the threat. Additionally, the display of both asset and threat weapon ranges would allow for an instant comprehension of aggressive capacity as well as vulnerability. These enhancements are described below and presented visually in figure 4.

Problem: Submarine location and interdiction.

3-D Display Fatures. Depicts bottom topography, wrecks, currents, temperature gradients, and acoustic range models for various platforms.

Benefits/Enhancements. This will allow warfighters to readily refine their search based upon a composite assessment of these factors, allowing for maximum effectiveness of each unit and the focusing of efforts on more probable contact locations.

MINE WARFARE

During the summer of 1995, the Defense Science Board conducted a study to determine areas necessary to concentrate upon to ensure 21st century military superiority (Kaminski, 1996). One of the major conclusions reached was that sea mines pose a significant threat to military forces in the

[3.] This report focuses on which cognitve tasks may benefit from the visualization of 3-D data. Comparative studies on how to effectively display the 3-D images will be needed to guide the implementation of the 3-D command and control console. See St. John and Cowen (1999) for a discussion on when and how to use 3-D perspective views for operational tasks.

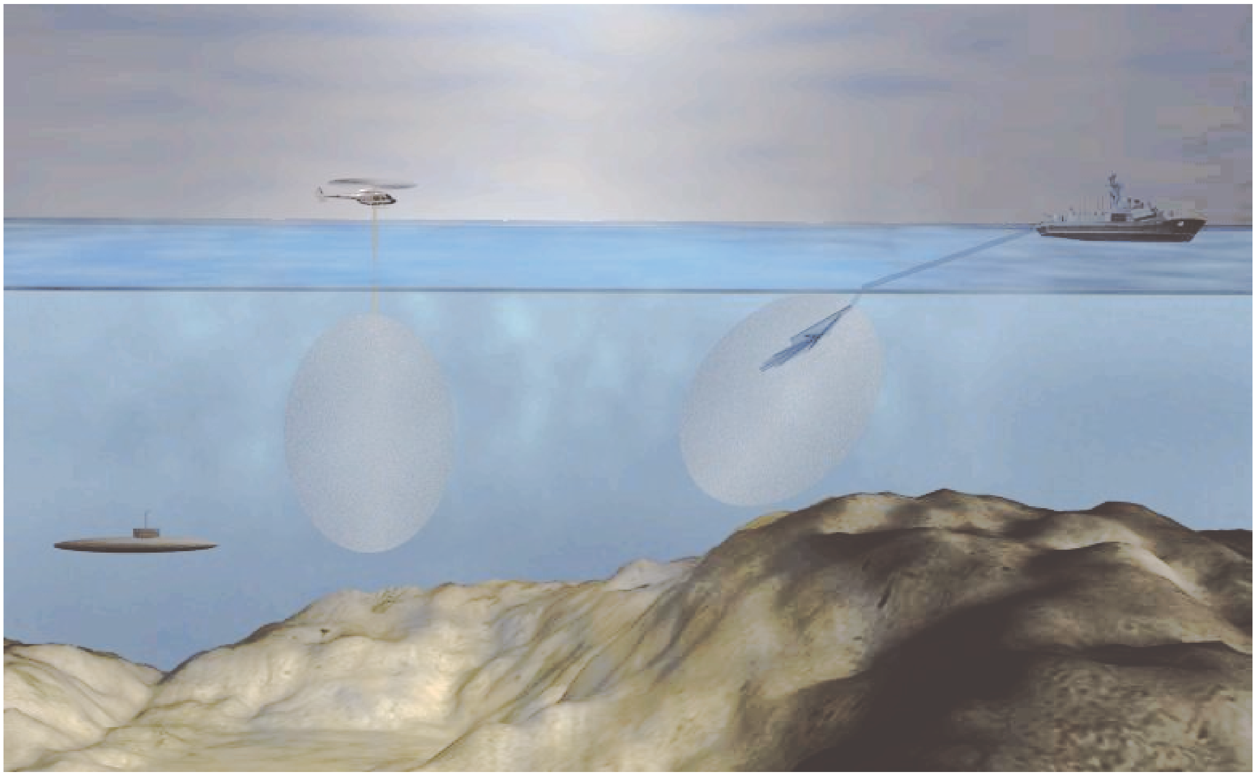


Figure 4. Undersea warfare depiction.

future. The breakup of the Soviet Union, with its enormous mine stockpile estimated at 450,000 sea mines, has created the potential for widespread availability of mines ranging from WWI vintage contact mines to advanced vertical rising and rocket propelled mines. Most of the damage to U.S. Navy warships in the last 10 years has come from mines, two of which were of WWI technology. There are currently 49 countries that possess mining capabilities, with 30 manufacturing countries and 20 known exporters.

One of the essential elements in an effective mine warfare capability will be to have mine countermeasures-oriented bottom mapping and environmental data bases, including acoustic and magnetic propagation characteristics of a particular area (Kaminski, 1996).

Survey results reveal that 3-D displays could aid greatly in the planning, briefing, and execution of mine countermeasure efforts with regard to both detection and interdiction. A bottom contour depiction including environmental factors would enhance all facets of mine warfare operations. These benefits are described below and presented visually in figure 5.

Problem: Mine location and interdiction.

3-D Display Features. Depicts bottom topography, wrecks, currents, bottom type, temperature gradients, acoustic and magnetic propagation, and depth. Additionally, shows mine locations (when discovered) and the positioning and maneuvering of a remote-controlled sled during interdiction efforts.

Benefits/Enhancements. This would allow planners and briefers to more rapidly describe the challenges associated with this specific effort as well as develop a more effective interdiction operation. Presenting a 3-D view of mine disposal efforts would provide a significant aid to the difficult task of directing a remote-controlled sled's mine disposal efforts while also keeping the ship on station. The increase in situation awareness would reduce both search and interdiction times by providing a more accurate and complete understanding of the search area and a visual depiction of disposal efforts.

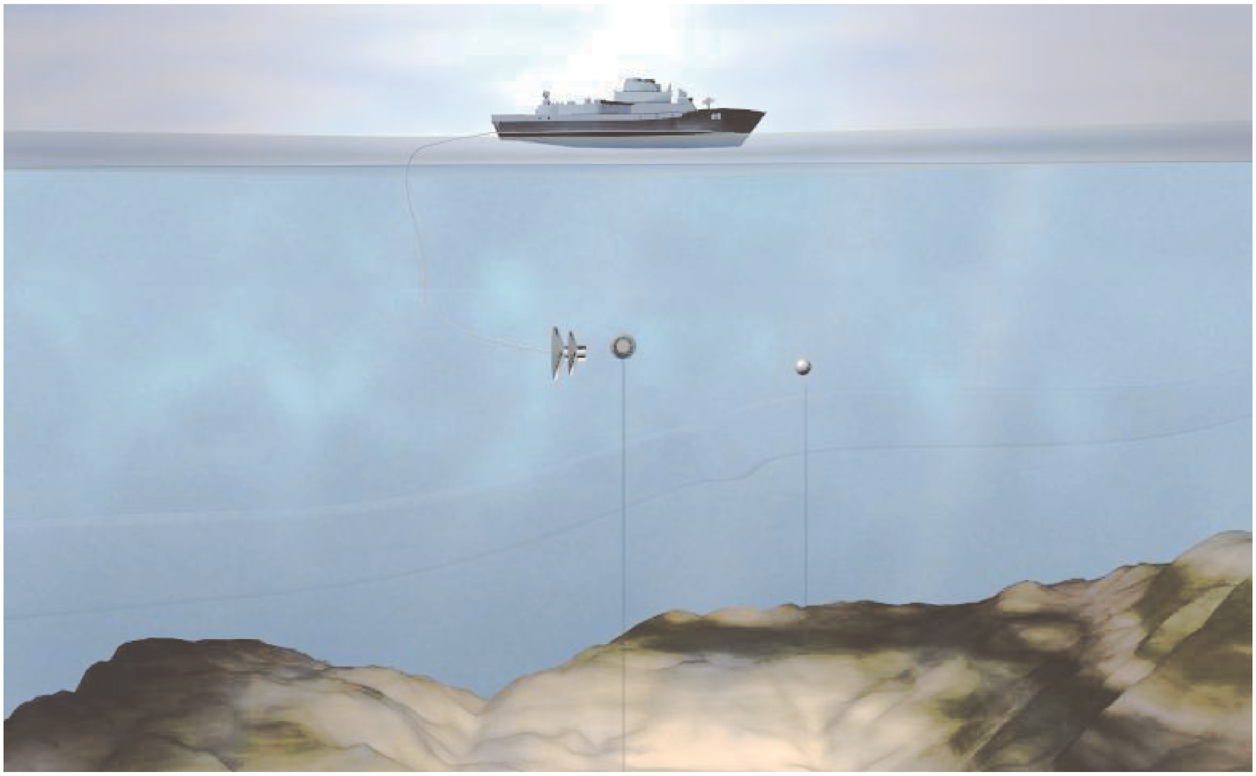


Figure 5. Mine warfare depiction.

SURFACE WARFARE

Strike missions are an integral part of the Fleet's overall theater force posture, and in the joint environment, provide the joint force commander with maritime support for land forces. As recently as 20 years ago, the furthest range surface strike weapon in the surface Navy's arsenal was the 5-inch/54 gun that had an effective range of 13 nautical miles. Today, however, the inclusion of Tomahawk extends naval surface strike missions hundreds of miles, greatly increasing their ability to interdict a distant target.

The U.S. Navy currently considers JMCIS to be one of the systems used to prosecute its land attack mission. JMCIS has been identified as a core element of the ATWCS (Advanced Tomahawk Weapons Control System), which is currently anticipated to evolve as the system controlling all shipboard land-attack weapons. Those experts interviewed stated that the inclusion of a 3-D display with terrain features would greatly enhance the battlespace manager's ability to seamlessly include topographical considerations into the decision making process by providing instant visual recognition, as well as providing an accurate overview of theater operations. These benefits are described below and presented visually in figure 6.

Problem: Support for the land-attack mission.

3-D Display Features. Depicts terrain elevation and cultural features with asset and threat elements included in the presentation.

Benefits/Enhancements. Provides increased comprehension of the battlespace area and data of sufficient quality to allow for the quick reaction delivery of Tomahawk and other extended-range weapons into a battlefront area. This could reduce the requirement for air support and negate weather constraints, allowing for a more economical and versatile use of precious assets.

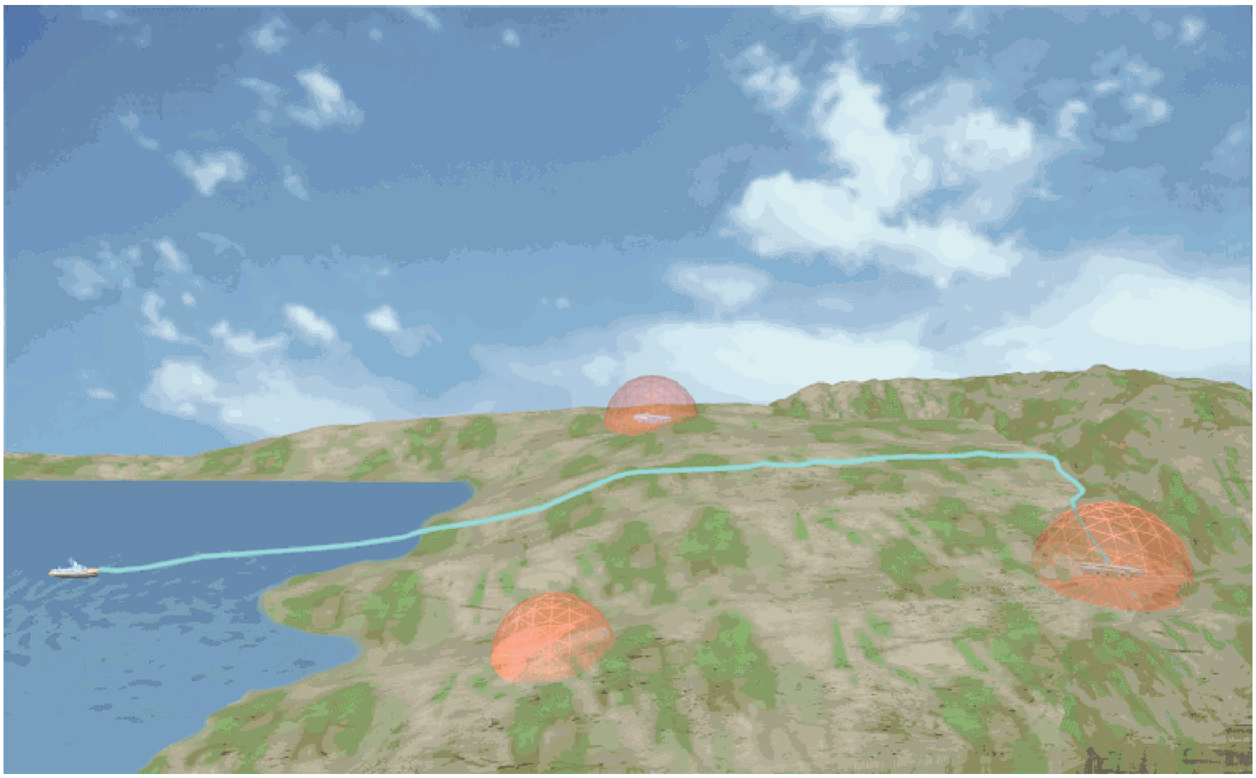


Figure 6. Surface warfare depiction.

AMPHIBIOUS WARFARE

The surface Navy's task for suppression of coastal defenses, operating either in support of or independently from any landing force, will consist of location and identification, followed by the use of surface fire or armed helicopters to neutralize the enemy. Suppression of coastal defenses presents some unique challenges. The battlespace is compressed; radar performance is reduced as a result of clutter, fold-over, and land masking; target identification and information preparation of the battlefield is difficult because of coastal terrain and target mobility; and reaction times to counter hostile fire are significantly reduced. Until recently, there has been little need for the Navy to focus on these difficulties. However, Arabian Gulf operations during the 1987-89 Tanker War and the 1991 Gulf War revealed the need for new capabilities to respond to the threat posed by antiship missiles.

Weapon and sensor overlays would allow for more advantageous positioning and use of assets through increased comprehension of the battle arena. Interviewees stated that the ability to display asset and threat ranges in 3-D would eliminate the confusion and inaccuracies associated with mentally incorporating these factors into a situation. This would facilitate more rapid and comprehensive awareness and would aid in planning, projection, and decisionmaking.

As with strike missions, experts indicated that a 3-D display could greatly benefit decisionmaking through a topographical representation of the assault area. This would allow for an easier and a more complete assault plan by providing a comprehensive “at-a-glance” battlespace overview. These benefits are described below and represented visually in figure 7.

Problem: Amphibious Assault Planning and Execution.

3-D Display Features. Depicts terrain elevation and cultural features with asset and threat elements included in the presentation. Depicts bottom topography, wrecks, currents, temperature gradients, and acoustic range models for various platforms. Depicts surface and air assets and potential threats, including weapon and sensor ranges.

Benefits/Enhancements. Visually shows more advantageous landing areas and provides a framework for the development of the battle scenario. This would allow the units involved in an assault to provide input and see the overall implication of adjustments made to the plan. The warrior would have a much better appreciation of the capability of specific roles in the operation and changes that may be necessary to overcome obstacles. Being able to view a 3-D representation of the unfolding battle situation would allow for increased comprehension of the battlespace, which would lead to a more timely and appropriate reallocation of assets. Gunfire support, Close Air Support (CAS), and troops could all be redirected to better accommodate the assault progress.

The enhanced display will also provide an increased awareness for ships involved with regard in self-defense. The 3-D presentation will assist deconfliction efforts between neutral, friendly, and hostile air units in the area. This task is difficult because the air contacts will be sporadically masked to radar by the mountainous terrain near the beaches through design or mission necessity. This expanded target discrimination ability allows for an increased reaction time and the ability to integrate more assets into the defensive equation. This includes allied air units as well as surface defensive forces. The 3-D depictions of engagement envelopes would promote more rapid and optimized targeting and employment decisions.

Another area of necessary concern to the amphibious group is the submarine threat. With the proliferation of Third World submarine acquisitions, almost any country can field underwater assets. The 3-D underwater topographic display will provide a depiction of areas in which to focus search efforts by presenting depth, thermal layer, and acoustic propagation data.

AIR WARFARE

Air warfare operations involve planning air defense in a given tactical situation, monitoring the tactical situation, assessing potential threats, and responding to the perceived threat. The success of air warfare operations is largely determined by the ability of the decisionmaker to rapidly and accurately comprehend and interpret the aircraft detected in a specific area (Dennehy, Nesbitt, and Sumey, 1994). To accomplish this, the decisionmaker must have effective computer-generated graphical displays of detected aircraft. The U.S. Navy’s “From the Sea” focus has given rise to primarily littoral operations for ships and battle groups, resulting in increasing difficulties for air warfare control and requiring more effectiveness from command and control displays.

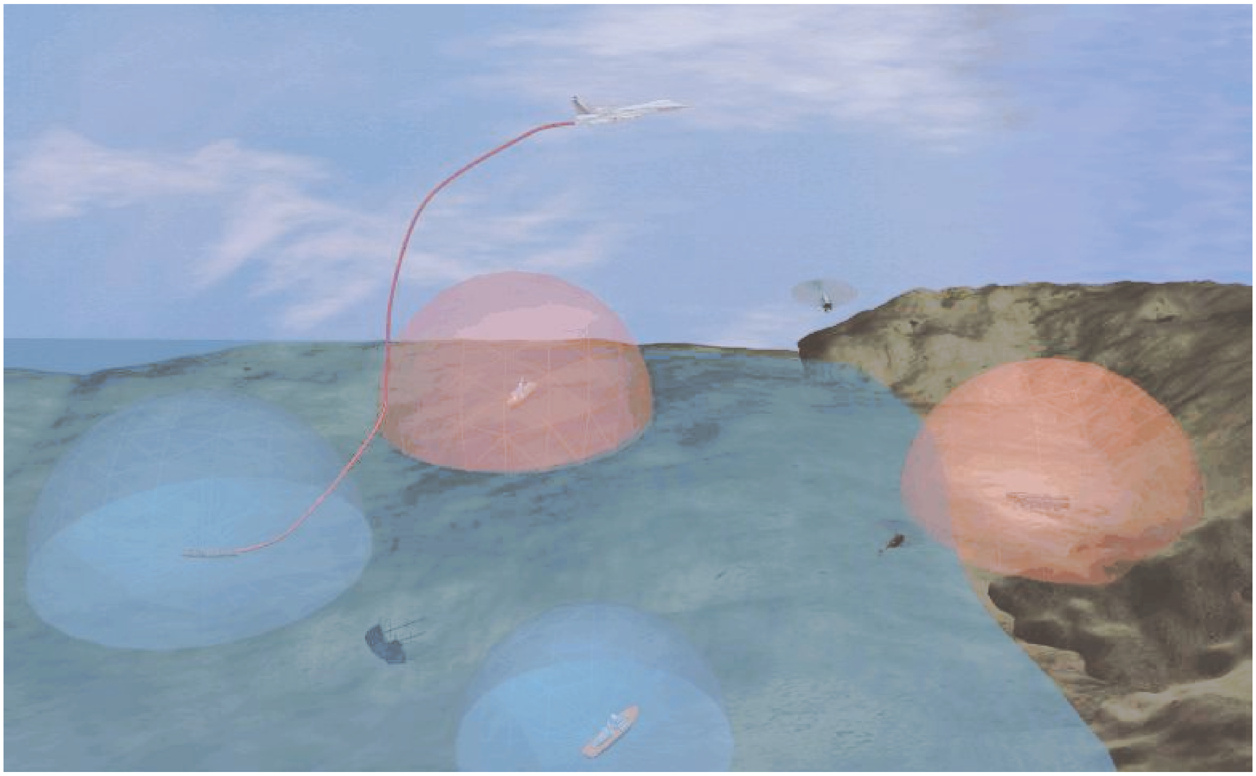


Figure 7. Amphibious warfare depiction.

Characteristics that must be considered when assessing threats include range, heading, speed, altitude, attitude (climbing or descending), and location. Each feature is measured by sensors on participating units and then correlated over time to form tracks indicating the presence of aircraft or missiles. Tracks are then exchanged with other units so that all participants have an inclusive picture. This has the undesired side effect of often displaying dual/false tracks. An automatic alert/correlation/resolution feature for dual tracks would simplify and enhance situation awareness by easing the operator workload and improving the display accuracy for decisionmakers. Dual/multiple tracks in a 2-D display can be annoying and disruptive, but in a 3-D display may cause extreme overload if they cannot be readily detected.

Current surveillance and combat systems present this information in a 2-D “plan view” showing the bearing and range of tracks in a specific area. The aircraft/missiles are depicted by symbols indicating location, speed, heading, and identity. Generally, the display shows a coastline map, any operationally significant areas, and sometimes depicts commercial airways to aid in deconfliction. To display additional information needed for monitoring assets and assessing threats, the operator must “hook” each track (select a track individually and press a button to view amplifying textual data). One of the most critical pieces of information represented in this manner is altitude data, and as such, this process is repeated frequently to enhance tactical assessment. A 3-D display would provide a track presentation that directly integrates altitude and attitude, relieving the user of the burdensome and error-prone task of associating numerical data with a graphical representation (Dennehy, Nesbitt, and Sumey, 1994). Continually monitoring displays can be tedious and tends to dull the awareness of the watchstander to situational changes. An additional enhancement to this display could be some type of alert mechanism (audio/visual) to highlight new or changing tracks of potential interest, which would support the desired result of reducing task load with regard to display monitoring. The best visual alert method is to make the target instantly much brighter, accompanied by flashing or chromatic change (NATO Defense Research Group, 1992).

To fully comprehend a threat, the operator must combine information from various graphical displays, including the associated symbology, as well as information from several consecutive textual readouts to develop a complete threat characterization. The effort to manually select tracks of interest, and then interpret the textual readouts and symbols, is difficult and distracts the user from the crucial decisionmaking process. A major error category involves the failure of the decisionmakers to take appropriate action when they are in range of an approaching contact's weapon (Hutchins and Rummel, 1995). Survey responses indicated that a 3-D presentation could reduce task loading/aid in the recognition of these envelopes and facilitate timely actions.

The interviewees stated that a 3-D terrain display would be extremely helpful when planning air defense systems for weapon and sensor system placement. This display would allow planners to immediately determine radar coverage and blind areas, and facilitate optimum placement of assets to minimize the enemy's ability to use terrain features to their advantage. The Commanding Officer of one of the ASCIET Command and Control units stated that it currently takes 3 to 4 days of operations before a good battlespace awareness with regard to terrain is reached. He concluded that the addition of a 3-D terrain inclusive display could make this awareness an immediate process, especially for novice personnel, who traditionally think in 2-D.

There are numerous other potential benefits of 3-D displays in an air warfare scenario. Allowing the user to control the perspective of the display can be an effective strategy for reducing clutter and resolving ambiguities (Ellis, McGreevy, and Hitchcock, 1987). In a 3-D presentation, the user should be able to view the tactical situation from any distance, location, and angle. This would enhance situation awareness by allowing them to visualize tactical data more freely and observe attributes that may go unnoticed with a fixed two-dimensional view. A 3-D perspective would complement planning support, principally aiding the ability to predict the effectiveness of air warfare system performance over a battlespace. This would be accomplished by depicting asset/threat radar and weapons coverage envelopes providing the unit station the opportunity to optimize offensive and defensive capabilities. This is particularly applicable in a littoral environment, where the effects of terrain can be significant with regard to radar masking. Expert interviewees suggested that displaying an air track history in 3-D could assist with the assignment of platform intent, greatly reducing the cognitive loading associated with this task. These benefits are described below and presented visually in figure 8.

Problem: Air Warfare Planning and Execution.

3-D Display Features. Depicts terrain elevation and cultural features with asset and threat elements included in the presentation. Depicts surface and air assets and potential threats, including weapon and sensor ranges, air track history, and weather phenomena.

Benefits/Enhancements. This new display would allow users to instantly see attitude, relative altitude, track history, and overlay engagement zones, allowing for a more rapid identification of possible hostile contacts, and would provide increased time to vector assets to intercept, identify, and, if necessary, deter hostile forces. The 3-D display would assist with deconfliction by instantly depicting adherence to RTF procedures. The inclusion of an air track history, weather considerations, weapon and sensor overlays, and terrain would provide a better understanding of an aircraft's intent by being able to call up and observe its path through a known environment.

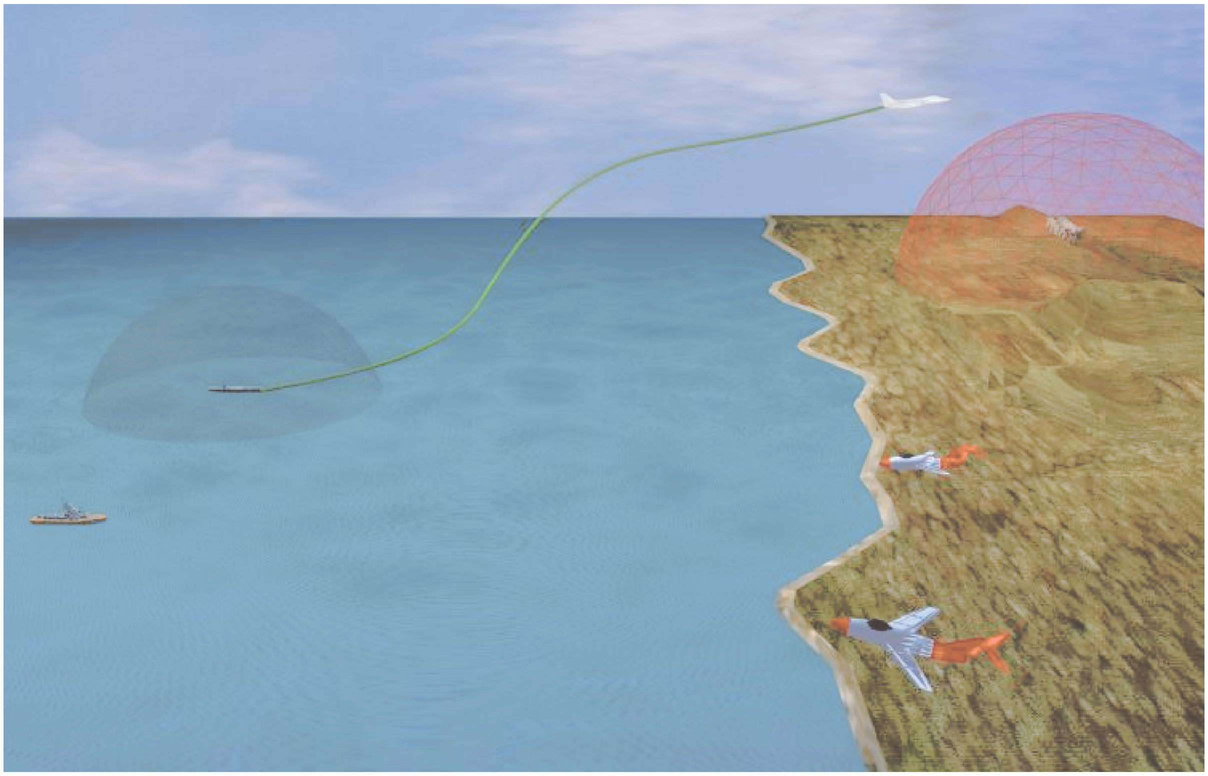


Figure 8. Air warfare depiction.

COMMAND, CONTROL, COMMUNICATIONS, COMPUTERS, INTELLIGENCE, SURVEILLANCE, AND RECONNAISSANCE (C4ISR)

The tremendous advances in C4ISR, along with dramatic improvements in ranges and capabilities of shipboard weaponry, will permit each U. S. Naval surface combatant of the 21st century to function as a “Capital Ship” when required. As such, it is imperative to display battlespace management information as complete and accurate picture to decisionmakers. Our study suggests that 3-D displays that include terrain and underwater topographic features represent the CTP better than any of the 2-D displays currently used. Additionally, the capability to do real-time 3-D depictions would assist with the predictions of unit movement/intentions. Several of the features that would support this enhancement include weather system data, satellite surveillance data, vulnerability windows, air track histories, and known/projected surface track histories.

CONCLUSIONS AND RECOMMENDATIONS

Based upon the above results, the following conclusions and recommendations are presented.

1. There is a need for a 3-D C4I display device in the Fleet.

2. We should develop a prototype 3-D display system to augment JMCIS display capabilities. The display should include:

    - Land terrain and underwater topography, including significant manmade features (cities, facilities, underwater wrecks and obstructions, etc.).

    - Air and underwater environmental data (weather systems, currents, ducting, thermal layers, etc.).

    - Automatic alert features for new or changing tracks (flashing, color change, size increase, etc.) and correlation features for automatic resolution of duplicate tracks.

    - Weapon engagement and sensor detection zones (both asset and threat).

    - Links to ACDS/NTDS/CEC for presentation of near-real-time aircraft data and air track histories.

REFERENCES

Adams, M. J., Y. J. Tenney, and R. W. Pew. 1995. "Situation Awareness and the Cognitive Management of Complex Systems," *Human Factors*, vol. 37, pp. 85–10.

Dennehy, M. T., D. W. Nesbitt, and R. A. Sumey. 1994. "Real-Time Three-Dimensional Graphics Display for Antiair Warfare Command and Control," *Johns Hopkins APL Technical Digest*, vol. 15, pp. 110–118.

Ellis, S. R., M. W. McGreevy, and R. J. Hitchcock. 1987. "Perspective Traffic Display Format and Airline Pilot Traffic Avoidance," *Human Factors*, vol. 29, pp. 371–382.

Endsley, M. R. 1987. "SAGAT: A Methodology for the Measurement of Situation Awareness." NOR DOC 87-83. Northrop Corporation, Hawthorne, CA.

Endsley, M. R. 1988. "Design and Evaluation for Situation Awareness Enhancement." *Proceedings of the Human Factors Society 32nd Annual Meeting* (pp. 97–101). 24-28 October, Anaheim, CA. Human Factors Society, Santa Monica, CA.

Endsley, M. R. and M. D. Rodgers. 1994. *Situation Awareness Information Requirements for En Route Air Traffic Control*. Federal Aviation Administration, Office of Aviation Medicine, Washington, D.C.

Gerson, C. W. 1997. "Situation Awareness and Dynamic Performance Training Systems: Some Reflections on the Literature," *Journal of Educational Technology Systems*, vol. 25, pp. 373–407.

Harwood, K., B. Barnet, and C. Wickens. 1988. "Situational Awareness: A Conceptual and Methodological Framework." *Proceedings of the 11th Symposium of Psychology in the Department of Defense*.

Hutchins, S. G. and B. K. Rummel. 1995. "A Decision Support System for Tactical Decision Making Under Stress." *Proceedings of the First International Symposium on Command & Control Research and Technology*. June, Washington, D.C. National Defense University, Washington, D.C.

Kaempf, G. L., S. Wolf, and T. E. Miller. 1993. "Decision making in the Aegis combat Information Center." *Proceedings of the Human Factors and Ergonomics Society 37th Annual Meeting* (pp. 1107–1111). 11-15 October, Seattle WA. Human Factors and Ergonomics Society, Santa Monica, CA.

Kaminski, P. D. 1996. "Three Musts for Affordable Naval Mine Warfare." National Defense Industrial Association Mine Warfare Conference. 11 June. Fort Myer, VA. National Defense Inustrial Association, Arlington, VA.

http://www.defenselink.mil/pubs/di96/di1169.html (20 Aug 1997).

Morrison, J. G., R. T. Kelly, and S. G. Hutchins. 1996. "Impact of Naturalistic Decision Support on Tactical Situation Awareness." *Proceedings of the Human Factors and Ergonomics Society 40th Annual Meeting* (pp. 199–203). 22-26 September, Philadelphia, PA. Human Factors and Ergonomics Society, Santa Monica, CA.

NATO Defense Research Group. 1992. “Applied Color Vision Research.” In *Color in Electronic Displays*, pp. 137–173, H. Widdel and D. L. Post, Eds. Plenum Press, New York, NY.

St. John, M. and M. B. Cowen. 1999. “Use of Perspective View Displays for Operational Tasks.” SSC San Diego Technical Report (In press).

Surface Warfare Officers School Command. 1996. *Joint Maritime Command Information System (JMCIS) Student Workbook.* Newport, RI.

APPENDIX A
JMCIS KEY CAPABILITIES

The following items are the JMCIS key capabilities:

1. Provide tactically significant information to support a Battle Group Commander's decisionmaking.
2. Integrate organic and non-organic information to support an all-source database manager.
3. Provide automatic Electronic Intelligence (ELINT) and attribute correlation processing of multi-source information to support accurate and consistent display of the tactical situation.
4. Support the CWC's (Composite Warfare Commander's) decisionmaking, including over-the-horizon targeting (OTHT).
5. Support current intelligence analysis and threat assessment.
6. Automate access to Navy Tactical Data System or Advanced Combat Direction System.
7. Provide communications connectivity with standard circuits including computer to computer.
8. Provide automated and manual access to characteristics and performance databases such as Naval Warfare Tactical database.
9. Provide tactical analysis, planning, decision aids, and briefing support.
10. Manage space and electronic warfare and Command and Control Warfare actions at the force level in support of all warfare areas.
11. Provide automated access to resident Tactical Environmental Support Systems (TESS) air and ocean databases and products.
12. Provide access to multi-projection, multi-resolution, and multi-source maps.
13. Provide automatic generation of formatted and Structured Query Language reports.
14. Provide input/output functions for all navigation sensors and systems users.
15. Provide remote HCI for parallel control, query, and readout of the Display Control Subsystem.
16. Integrate data communications, processing, and display technologies to provide timely environmental support, including assessments of the environment upon specific platforms, sensors, and weapons systems.

APPENDIX B

WATCHSTATION FUNCTIONS

The Combat Information/Direction Center performs the functions of gathering, processing, evaluating, displaying, and disseminating tactical information[*]. There are various watchstanders that support these functions. These include:

1. Radar Operators. Their mission is to adjust radar-operating parameters to maximize coverage of the surveillance area, minimize the effects of clutter and land mass, and defend against other source active jamming.

2. Passive Sensor Operators. These personnel operate and adjust passive sensor systems to detect and classify sources of acoustic and electromagnetic emissions.

3. Detector/Trackers. These personnel assess combined data from active and passive sensors to determine if a contact actually represents an entity or clutter. They must also determine if contacts from multiple sources represent the same entity or multiple contacts (correlation of tracks).

4. ID Operators. These personnel use Identification Friend or Foe (IFF) interrogation systems, active and passive sensors, intelligence reports, geographic plots, and voice communications to come up with a "best guess" as to the identity of valid contacts.

5. Track Supervisor. This individual oversees Sensor Operators, Detector/Trackers, and ID Operators to ensure an accurate and all encompassing picture is presented to the TAO. This person also coordinates the operation of tactical data links to exchange information with other ships and aircraft (determines which internal contacts will be transmitted and which external tracks correlate to those held by ownship sensors).

6. Tactical Action Officer (TAO). This person supervises and monitors the activity of all previously mentioned watchstanders, and provides direction when necessary. He/she uses large-screen display (LSD) systems that depict geography and contact activity from ownship sensors as well as external data links to evaluate area situations and attempt to predict future activity. Based on decisions and orders from higher authority, the TAO initiates both offensive and defensive responses with available weapons systems.

7. Warfare Coordinators. They direct the activities of sensor operators and detector/trackers, as well as supervising the employment of offensive and defensive weapons systems. There are three separate warfare coordinators, reflecting the three major warfare areas. These are:

   a. Air Warfare Coordinator (AWC). They supervise air search radar operators, air detector/trackers, air weapon system operators including combat aircraft controllers, Surface-to-Air Missile (SAM) system operators, and gun system operators.

   b. Surface Warfare Coordinator (SUWC). They supervise surface search radar operators, surface detector/trackers, and surface weapon system operators including surface combat aircraft controllers, cruise missile operators, and gun system operators.

---

[*] W. Pinto. 1997. "Functions of the Shipboard Combat Information Center and Three Dimensional Displays." Unpublished manuscript.

c. Under Sea Warfare Coordinator (USWC). They supervise acoustic sensor operators (both active and passive), subsurface detector/trackers, and anti-submarine weapon system operators including USW aircraft controllers and torpedo system operators.

APPENDIX C
TASK SURVEY

For each of the following tasks, please provide a rating of one through five in the areas of criticality, frequency, and difficulty, with one being low and five being high. For purposes of this survey, use the following amplification.

Criticality- Importance

Frequency- How often performed

Difficulty- Complexity or tediousness of learning or performing

	C	F	D
1. Locate significant topographical features on an operational area chart.	__	__	__
2. Determine the effects of atmospheric conditions on platform capabilities.	__	__	__
3. Employ environmental products to identify significant oceanographic features such as currents, oceanfronts and eddies, and upwelling.	__	__	__
4. Recognize and classify elements of U. S. and allied forces.	__	__	__
5. Determine overall capabilities of U. S. and allied forces.	__	__	__
6. Recognize and classify elements of threats: Air.	__	__	__
Surface.	__	__	__
Subsurface.	__	__	__
7. Determine a contact's position (location, altitude/depth).	__	__	__
8. Assess a contact's position relative to other contacts.	__	__	__
9. Evaluate a contact's motion (heading, velocity, ascent/descent).	__	__	__
10. Determine threat capabilities.	__	__	__
11. Direct the control of aircraft in air intercepts/engagements (real/simulated).	__	__	__
12. Direct the control of aircraft in surface search/engagements (real/simulated).	__	__	__
13. Direct the control of aircraft in undersea search/engagements (real/simulated).	__	__	__
14. Direct the control of surface units in air defense (real/simulated).	__	__	__
15. Direct the control of surface units in surface actions (real/simulated).	__	__	__
16. Direct the control of surface units in undersea search/engagements (real/simulated).	__	__	__
17. Predict future actions of threats.	__	__	__
18. Adopt strategies and refine contingency plans based on predicted threat actions.	__	__	__
19. Develop a general battlespace overview.	__	__	__
20. Maintain awareness of communications status.	__	__	__

21. Resolve contact ambiguities. __ __ __

Please use the space below to comment on specific areas where you believe a three dimensional (3D) display could enhance situations discussed above or any other items of interest.

Your assistance is greatly appreciated.

APPENDIX D
INTERVIEW TECHNIQUES

ACTA INTERVIEW PROCESS

1. The Task Diagram. The Task Diagram acts as an advance organizer, providing an overview of a specific task and identifying the cognitively complex elements of the task.

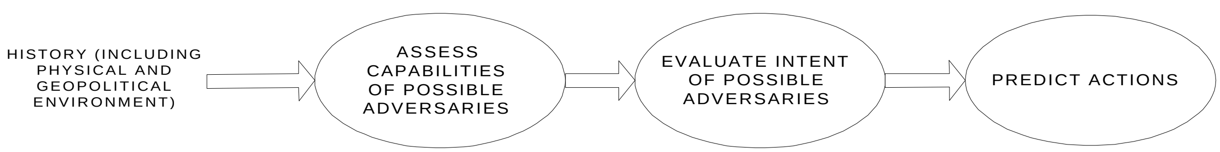
2. A Knowledge Audit. After the Task Diagram, a Knowledge Audit is performed, looking at parts of the task to provide details and examples of cognitive elements of expertise.

3. A Simulation Interview. After completion of the Knowledge Audit, a Simulation Interview is then conducted to provide a view of the expert's problem solving processes in context.

Depicted below are the ACTA interview techniques. Depending upon the individual being interviewed, one or two Task Diagrams were developed to provide a broad overview of the tasks required to perform a specific action. The circled steps represent areas that require cognitive skills.

TASK DIAGRAM

Evaluate Area Picture to Predict Future Actions.



KNOWLEDGE AUDIT

Assess Capabilities of Possible Adversaries

Example	Cues and Strategies	Why Difficult for Novice?
Past and Future Example		
Big Picture Example		
Noticing Example		

SIMULATION INTERVIEW

(1) Recount a specific scenario to the interviewee (amphibious assault, undersea warfare, mine interdiction, etc.). (2) Elicit a list of major events in the scenario and record. (3) Elicit information in the remaining columns for each event.

Events	Actions	Situation Assessment	Critical Cues	Potential Errors

APPENDIX E

PROBE QUESTIONS

1. What, if anything, about tactical displays is difficult to you to use/understand?

2. Do you ever have any difficulty with data input (i.e. can it be labor intensive or difficult to perform/understand)?

3. Is the information that is displayed ever confusing? If so, in what way?

4. What do you believe could be done to make the displayed information more understandable?

5. Are there any types of information not currently displayed that you believe would aid in understanding the Tactical Picture and Decisionmaking? If so, what?

6. What types of decisions have you made based on the information displayed?

7. Can you tell me about your thought process while analyzing and making decisions based on displayed information (i.e., confirm with other sources, question the timeliness of the data, etc.)?

8. Are there occasions when there is more information displayed than is easily understandable?

   Does this detract from your ability to interpret/analyze/make decisions based on the display?

9. Can you think of any instances where it might be beneficial to have information displayed in a 3-D vice 2-D format? If so, what and why?

APPENDIX F

TASK SURVEY COMMENTS

Respondent 1. The USN/USMC team with their CRU/DES (Cruiser/Destroyer) assigned escorts probably have the biggest requirement for a 3-D picture. These units typically work in the littoral where the 3D presentation of landmasses could better facilitate their solution.

The USMC, on the other hand, use a 3-D picture as their starting point. They are very concerned about topographical features in their push ashore to previously identified objectives.

There is definitely a need for such a project. The USMC might have to be told this, but there is a need.

Respondent 2. Use the display to do more than just display positions. If it could sense the proximity between displayed items, like contact to contact and contact to airplane, contact to shoreline, etc. Then expand on that to contact weapon range to ownship, or the other way around, ownship weapons range to contact, etc. And have some visual cue (like color or shape change) indicate these transitions so that with time the brain would quickly link the visual cue changes to various meanings like a language and simply absorb the significance of the entire display. I fly airplanes. I'm an NFO. We like the old fashioned gauges with needles because we don't really read the numbers, we just "know" where the needle is supposed to be. We know the significance of a change in needle position. We hate digital readouts because it takes longer to read and it doesn't tell a story. In other words, adding more info to a displayed contact like its mode II, and track number and altitude and speed is not as good as representing these sorts of things in some other visual way that more intuitively paints a picture.

Respondent 3. One specific area where a 3-D display could enhance understanding is with amphibious ships in a littoral environment where both sea and land are major planning considerations and factors in completing an assigned mission.

The USMC and amphibious sailors probably have an increased need for a 3-D product vice open-ocean warfighting.

APPENDIX G
ACTA TASK DIAGRAM RESULTS FROM SWOS INTERVIEWS

Interviewee   Steps identified for evaluating an area picture to predict future actions

1.	History (including geopolitical and physical environment)	Assess force structure of friends and adversaries	Determine ownship equipment configuration and evaluate/adjust	Develop mental contingencies for possible actions	
2.	History (including geopolitical and physical environment)	Assess threat type and location, assess friendly capabilities	Assess environmental parameters affecting sensors	Conduct surveillance of area	Evaluate contingencies based upon possible actions
3.	History (including geopolitical and physical environment)	Assess threats and friendlies	Anticipate logical future actions	Refine contingency plans	Rehearse reactions to possible aggression
4.	History (including geopolitical and physical environment)	Assess their capabilities and your requirements to counter	Adjust friendly assets based upon availability		
5.	View current contact picture	Assess environmental picture	Adjust sensors based upon environment	Evaluate future actions based upon mission, threat, & assets	
6.	History (including geopolitical and physical environment)	Determine picture (friends, others, adversaries)	Evaluate changes over entire battle picture	Mentally refine contingency plans based upon changing situation	
7.	History (including geopolitical and physical environment)	Assess friendly and adversarial assets	Clarify threat area and resolve unknowns	Decide best way to accomplish mission given potential threats	

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	March 1999	Final: June 1998 to March 1999

4. TITLE AND SUBTITLE

COGNITIVE AND BEHAVIORAL TASK IMPLICATIONS FOR THREE-DIMENSIONAL DISPLAYS USED IN COMBAT INFORMATION/ DIRECTION CENTERS

5. FUNDING NUMBERS

C: N66001–96–D–9000
PE: 0603707N
AN: DN308298
WU: CE31

6. AUTHOR(S)

M. F. Eddy, H. D. Kribs,
Instructional Science and Development, Inc.

M. B. Cowen
SSC San Diego

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Instructional Science and Development, Inc.
14117 Perdido Key Drive
Pensacola, FL 32507–9512

SSC San Diego
San Diego, CA 92152–5001

8. PERFORMING ORGANIZATION REPORT NUMBER

TR 1792

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Office of Naval Research
800 North Quincy Avenue
Arlington, VA 22217-5160

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT	12b. DISTRIBUTION CODE
Approved for public release; distribution is unlimited.	

13. ABSTRACT *(Maximum 200 words)*

This report discusses an investigation to determine which tactical information should be displayed in three dimensions (3-D), as visualized data that would be beneficial to the warfighter's understanding of the battlespace. A cognitive task analysis was conducted using warfighting personnel from Surface Warfare Officer's School (SWOS), Joint Maritime Command Information System (JMCIS) instructors at Navy Technical Training Center, Corry Station, and participants at the "All Service Combat Identification and Evaluation Team, 1997" combat training exercise. Our task analysis found that a 3-D display could enhance situation awareness by providing a succinct, comprehensive, and readily discernable presentation of the common tactical picture. 3-D displays could aid tactical decisionmakers in three general cognitive/perceptual areas: (1) assessing the force structure of friends, neutrals, possible adversaries, and noncombatants, (2) anticipating possible future actions based upon capabilities, historical precedent, and current political climate, and (3) refining and rehearsing contingency plans based on an assessment of the possible threat. Our analysis examined these processes and determined that a 3-D display could provide enhancement in submarine and mine location/interdiction, amphibious assault/land support, and air warfare planning and execution.

14. SUBJECT TERMS

Mission Area: Command, Control and Communications
decision support
decision aids/decisionmaking
man-machine interface
3-D display

15. NUMBER OF PAGES

54

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	SAME AS REPORT

INITIAL DISTRIBUTION

Defense Technical Information Center Fort Belvoir, VA 22060–6218	(4)
SSC San Diego Liaison Office Arlington, VA 22202–4804	
Center for Naval Analyses Alexandria, VA 22302–0268	
Navy Acquisition, Research and Development Information Center (NARDIC) Arlington, VA 22244–5114	
GIDEP Operations Center Corona, CA 91718–8000	

Approved for public release; distribution is unlimited.